

**Studies of Anadromous Dolly Varden
(*Salvelinus malma*) (W.) of the
Big Fish River, NT, Canada, 1972-1994**

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STUDIES OF ANADROMOUS DOLLY VARDEN
(*SALVELINUS MALMA*) (W.) OF THE
BIG FISH RIVER, NT, CANADA, 1972-1994

by

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ABSTRACT

Sandstrom, S. J. and L. A. Harwood. 2002. Studies of anadromous Dolly Varden (*Salvelinus malma*) (W.) of the Big Fish River, NT, Canada, 1972 – 1994. Can. Man. Rep. Fish. Aquat. Sci. 2603: vi + 31 p.

Anadromous Dolly Varden (*Salvelinus malma*) spawn and over-winter at the "Fish Hole" on Cache Creek, a tributary of the Big Fish River. Subsistence fishermen, primarily from Aklavik, NT, have long harvested the Dolly Varden from this stock. In the early 1980's, declines in the number and size of the fish caught (compared with catches in the 1970's) provided strong indication to the community, Fisheries Joint Management Committee (FJMC) and DFO that the stock was in a state of decline. In June 1987, the community of Aklavik decided to close the Big Fish River to all fishing to allow the stock to recover, and it remained closed for five years. A small quota has been in place since the river was reopened in 1992, with an average of less than 50 Dolly Varden taken annually in the river or its tributaries. From 1990-1999, on average, 216 Dolly Varden were harvested annually along the shores of Shingle Point, and up to 50% of these may have been of Big Fish River origin.

Estimates of the size of the stock in 1973 (13,500 and 20,700) were higher than more recent estimates (in 1991, 2232 with 95% CI 1716-2748; in 1994, 4477 with 95% CI 2305-6649), suggesting there has been a decreasing trend over the past twenty years. The stock has apparently not recovered in size, despite reduced fishing pressure since 1987. While the size of the stock has not increased, the size and age of the fish have. Between 1986 and 1994, mean length and age increased, while the sex ratio among the anadromous spawners remained highly skewed toward females (e.g., 6:1). Age at first maturation for Big Fish River females is lower (e.g., 5 years) than in neighbouring systems which are relatively unexploited. The majority of mature Dolly Varden of the Big Fish River spawn annually, as opposed to those from neighbouring stocks that spawn every second or third year.

The paucity of spawning anadromous males, the apparent absence of "large silvers" (current-year non-spawning [resting] adults), lower size-related fecundity and larger egg size are thought to cumulate thus reducing the overall reproductive potential of the stock. Continued fishing in Yukon coastal waters, although minimal, may be hampering the recovery process. The apparent reduction in the amount of available spawning and over-wintering habitat at Cache Creek as a result of natural processes is also thought to be a contributing factor to lack of recovery in the abundance of the stock.

Key Words: Dolly Varden, Big Fish River, spawning, over-wintering, resting, harvests, habitat changes.

RÉSUMÉ

Sandstrom, S. J. and L. A. Harwood. 2002. Studies of anadromous Dolly Varden (*Salvelinus malma*) (W.) of the Big Fish River, NT, Canada, 1972 – 1994. Can. Man. Rep. Fish. Aquat. Sci. 2603: vi + 31 p.

Des Dolly Varden (*Salvelinus malma*) anadromes se reproduisent et passent l'hiver au « Fish Hole », situé sur le ruisseau Cache, un affluent de la rivière Big Fish. Des pêcheurs de subsistance, d'Aklavik (T.N.-O.) surtout, exploitent depuis longtemps ce stock de Dolly Varden. Au début des années 1980, les baisses du nombre et de la taille des poissons capturés (par rapport aux prises des années 1970) ont fortement indiqué à la collectivité, au Comité mixte de gestion de la pêche (CMGP) et au MPO que le stock était en déclin. En juin 1987, la collectivité d'Aklavik a décidé d'interdire toute pêche dans la rivière Big Fish afin de permettre au stock de se rétablir. L'interdiction a été maintenue pendant cinq ans, jusqu'en 1992. Depuis, on impose un petit quota; en moyenne, moins de 50 Dolly Varden sont pêchés chaque année dans la rivière et ses affluents. De 1990 à 1999, 216 Dolly Varden, en

moyenne, sont capturés annuellement le long de la pointe Shingle; jusqu'à 50 % de ces prises pourraient avoir été originaires de la rivière Big Fish.

Les estimations de la taille du stock en 1973 (13,500 et 20,700) étaient plus élevées que les estimations plus récentes (en 1991 : 2232 – IC à 95 % de 1716 à 2748; en 1994 : 4477 – IC à 95 % de 2305 à 6649), ce qui porte à croire que la tendance est à la baisse depuis 20 ans. Malgré la réduction de la pression de pêche depuis 1987, le stock ne semble pas s'être rétabli, mais, contrairement à la taille du stock, la taille et l'âge des poissons ont augmenté. De 1986 à 1994, la longueur et l'âge moyens ont augmenté, alors que le sex-ratio des géniteurs anadromes est resté fortement biaisé en faveur des femelles (6:1). L'âge à maturité des femelles est moindre dans la rivière Big Fish (5 ans) que dans des cours d'eau avoisinants qui sont peu exploités. La majorité des Dolly Varden matures de la rivière Big Fish fraient chaque année, tandis que ceux des stocks avoisinants ne fraient qu'aux deux ou trois ans.

On croit que la rareté des géniteurs mâles anadromes, l'absence apparente de « gros argentés » (adultes [au repos] qui ne fraient pas une année), la baisse de la fécondité liée à la taille et l'augmentation de la taille des œufs se combinent pour réduire le potentiel de reproduction global du stock. La poursuite de la pêche, même à un niveau très faible, dans les eaux côtières du Yukon pourrait nuire au processus de rétablissement du stock. On croit que la réduction apparente de la disponibilité de frayères et de lieux d'hivernage dans le ruisseau Cache, laquelle est attribuable à des processus naturels, est aussi un facteur qui empêche le stock de se rétablir.

Mots clés : Dolly Varden, rivière Big Fish, fraie, hivernage, repos, pêches, modifications de l'habitat.

INTRODUCTION

The Yukon North Slope and adjacent portions of the Northwest Territories have six systems that are known to support genetically discrete stocks of the northern form of Dolly Varden (*Salvelinus malma*) (Walbaum) (Reist 1989; Reist et al. 1997). These rivers, in order from west to east are Joe Creek, and the Firth, Babbage, Big Fish, Rat and Vittrekwa rivers (Fig. 1).

The anadromous Dolly Varden stock of the Big Fish River spawn and over-winter at the "Fish Hole" on Cache Creek, a tributary of the Big Fish River (Fig. 1). The Fish Hole is the only known spawning and over-wintering area for this stock. At the Fish Hole, a small portion of the stream (i.e., 3 to 4 km) remains as open water during the winter due to a perennial thermal spring.

Several different life history types of Dolly Varden are found at this location. In addition to anadromous or sea-run fish of both sexes, there is a non-anadromous type called "residual" and made up completely of males. These co-occur with the anadromous type. There is also an isolated non-anadromous type found upstream of an impassable waterfall at the uppermost portion of the Fish Hole.

Subsistence fishermen, primarily from Aklavik, NT, have long harvested Big Fish River Dolly Varden. Declines in the number and size of fish caught (compared with catches in the early 1970s) provided a strong indication to the community, the Fisheries Joint Management Committee (FJMC) and DFO that the stock may be at serious risk due to over-harvesting. In June 1987, the community of Aklavik passed a motion to close the Big Fish River to all fishing for a period of five years, to allow the stock to recover. The FJMC put this closure into effect through DFO regulation and worked with Aklavik during the ensuing years to monitor the recovery of the stock.

In 1972 and again in 1984, DFO undertook mark-recapture studies at the lower reaches of the Big Fish River and at the Fish Hole on Cache Creek. The purpose of these studies was to estimate the size of the Big Fish River stock (Stein et al. 1973; Gillman et al., cited in

Kristofferson and Baker, 1987). In 1987 and 1988, the beginning of the fishing closure, DFO and FJMC undertook weir assessment studies to determine the status of the stock (MacDonnell 1988; Fehr and Archie 1989). At the end of the closure, a number of studies were conducted, funded by the FJMC (Harwood, L., Sandstrom, S., unpubl. data). These included:

- an enumeration of the upstream run using a deflection-board weir in 1991;
- visual counts of adults on the spawning grounds in 1991, 1992 and 1993;
- floy tagging in 1993 and 1994 to estimate stock size, examine movements, determine the relative proportion of Big Fish Dolly Varden caught in coastal fisheries, evidence for sequential spawning;
- dead sampling in 1991, 1993 and 1994 to determine age, growth, and vital parameters; and,
- monitoring of community harvests at Shingle Point (1993, 1994, 1995 and 1996) and at the mouth of the Big Fish River (1992 and 1996) to determine the size and characteristics of the catch, and to collect samples for genetic analyses.

THE FISHERY

Historically, Big Fish River Dolly Varden were harvested in three locations:

- from Yukon coastal waters during summer feeding and migrations;
- at the mouth of the Big Fish River during August as they moved back up the river to spawning and over-wintering areas in the tributary; and
- at the spawning and over-wintering site (known locally as "Fish Hole") on Cache Creek in October and November (Fig. 1).

Fishing along the coast and at the mouth of the Big Fish River was conducted primarily with 51-102mm (2-4") mesh gillnets. Seine nets of 26mm mesh or a small mesh gillnet were used to "sweep" Dolly Varden from the pools at the Fish Hole. Records from 1972 indicate a harvest of 3000-5000 Dolly Varden from the lower reaches and 5000-7000 from the Fish Hole. In 1973, the total harvest from the river,

including both the lower reaches and the Fish Hole, was estimated at 3700 fish including catches from a small commercial fishery (quota 900 kg) which was in place during this time.

No further information is available on annual harvests until 1985, when the total catch from the lower reaches and the Fish Hole was estimated at 1000. In 1986, the last year of fishing before the closure, the subsistence fishery was estimated to have removed 200 Dolly Varden from the lower reaches and 1660 from the Fish Hole (Sparling and Stewart 1986).

At the time of the closure, and up until 1991, there was no fishing for Big Fish River Dolly Varden at either the mouth of the river or at the Fish Hole. Small exploratory fisheries were opened at the mouth (1992, 1994-96) and at the Fish Hole (1993, 1995, 1996 and 1997), when requested by the community of Aklavik. Catches were minimal at all of these locations in all years (e.g., <50/year).

In 1992 and 1996, the years when the exploratory fishery at the mouth of the Big Fish River first re-opened, the community monitors were the only people fishing. In 1992, only 24 Dolly Varden were caught between August 10-27, and in 1996, 19 Dolly Varden were taken between August 12-20, 1996. No fishing took place at the mouth of the river in the summer or fall of 1994 and 1995, although a small quota was in place.

Before, during and since the closure, Dolly Varden harvesting has continued at Shingle Point (Fig. 1) during the months of July and August (Table 1). Assuming that 50% of the Dolly Varden caught at that location are from the Big Fish River stock (Fabijan 1991a,b,c; Fabijan 1995 a,b,c,d; Fabijan 1997a,b; Fabijan 1998; Stephenson 2000), the mean annual harvest level for Big Fish River Dolly Varden (1986-1999) at Shingle Point averaged 100.

STOCK DELINEATION

There are at least six known populations of the northern form of Dolly Varden in Canada. Studies using both morphology and genetic methods have confirmed the discreteness of fish from four river systems (Firth, Babbage, Big

Fish and Rat; Reist 1989). Data also indicate that fish from Joe Creek, a tributary of the Firth River, may be distinct from those that spawn in the Firth River (Reist 1989). Additional genetic information (i.e., sequence variation in mitochondrial DNA) confirms that these populations are all different from each other but mix along the coast during summer feeding and migrations (J. Reist, unpubl. data).

The genetic differences detected between spawners from the Big Fish River and those at adjacent rivers provide evidence that these Dolly Varden exhibit a high degree of homing during years when they are in spawning condition (Reist 1989; Reist et al. 1997). In addition, results from tagging programs on this and other neighbouring rivers have determined that straying of spawners and silvers between the systems is incidental if at all.

In 1989 at the Rat River (Stephenson and Lemieux 1990) and between 1990-1992 at the Babbage River (Sandstrom et al. 1997), the nearest neighbouring systems to the Big Fish River containing Dolly Varden, a total of 2580 floy tags were applied to Dolly Varden. To date, none of these tags have been recovered in the Big Fish River system, despite four seasons of sampling (1991-1994)(DFO 2001).

As well, floy tags were applied to Big Fish River Dolly Varden in 1984 (n=444), 1987 (n=599), 1988 (n=178), 1991 (n=435), 1993 (n=149) and 1994 (n=285). Although recapture mechanisms have operated on the Babbage River (weir, 1990-1992) and Rat River (subsistence fishery, up to the present), Dolly Varden tagged at the Big Fish River have only been recaptured in mixed fisheries along the Yukon North Slope and in the Big Fish River itself.

STOCK PARAMETERS

There have been 17 studies done on anadromous Dolly Varden of the Big Fish River since the 1980's (Table 2). Results from 1987, 1988, and 1991-1994 studies at the Big Fish River provide data on changes in biological parameters for this stock since the closure of the fishery in 1987. In addition, data from the neighbouring Babbage River Dolly Varden stock which receives little or no fishing

pressure, and Rat River Dolly Varden stock which is subject to intense subsistence fishing pressure, are available and are compared to the Big Fish River data. Many of the comparisons involve information collected from spawning females, the most numerous sex and life history stage found in the Big Fish River.

Stock Size

There were 11 attempts to calculate the size of the anadromous stock between 1972 and 1994, using mark-recapture estimates (Table 3). In 1972, a mark-recapture study done at the mouth of the Big Fish River yielded an estimate of the anadromous stock size being 20,700 Dolly Varden (95% CI 15,800-27,600, accounting for an estimated catch of 4000; Stein et al. 1973). A second mark-recapture study was done in fall 1972 at the Fish Hole, and produced an estimate of 13,500 Dolly Varden (95% CI 11,300-16,000, accounting for an estimated catch of 6000 at the Fish Hole).

Another mark-recapture study was conducted by DFO in 1984 (Gillman et al., cited in Kristofferson and Baker, 1987). Assuming no mortality of tagged fish since 1984, a Peterson estimate of stock size in 1985 was 9300 (95% CI 6,300-14,300). Annual mortality calculated from a sample of the catch in 1985 was $A=0.50$. Adjusted mortality based on this rate produced a Petersen estimate of 4600 (95% CI 3100-7,100) (Kristofferson and Baker 1987).

In 1987, a rigid conduit-pipe weir was erected on Cache Creek (Fig. 1) to determine the size of the upstream run by direct enumeration (MacDonell 1988). High water levels inundated the weir before the run ended, and only 3100 Dolly Varden were counted (August 13 to 23). A Petersen estimate of the stock was conducted at the Fish Hole later that fall, and produced an estimate of 9076 Dolly Varden (95% CI 6 300-13,800) greater than 200 mm in length. This estimate consisted of approximately 1500 spawners and 7600 non-spawners for that year.

Given the wide confidence interval of the 1987 estimate, a second attempt was made to enumerate the run in 1988, again using a conduit weir (Fehr and Archie 1989). However,

high flows and debris again washed out the weir part way through the run, and only 1244 Dolly Varden were counted (August 2-28 - only operational for 12.5 days during this interval due to high water).

Two Petersen estimates were made at the Fish Hole that fall, yielding estimates of 5800 Dolly Varden and 8500 Dolly Varden, but again the confidence intervals were wide (95% CI 4300-12,800). A third Peterson estimate was possible using the number of Dolly Varden tagged in 1987, and recaptured at the weir in 1988 (Appendix I). Accounting for recruitment and tag loss, the estimate calculated using these data is 7379 (95% CI 5779-9279). Finally, a fourth estimate was done using both the number of Dolly Varden tagged during the weir enumeration in 1987 and 1988 and the number recaptured during the fall survey in 1988. This Bailey's Triple-Mark-Recapture estimate calculates the size of the anadromous population at 6766 (95% CI 1845 - 11,687) in 1991 (Appendix II). Based on the average of these four estimates, it appears that in 1987-1988 there were approximately 6000-8000 anadromous Dolly Varden in this stock.

Two important conclusions were drawn from the 1987 and 1988 studies:

- (1) that a rigid conduit-pipe weir was unsuitable for the enumeration of Dolly Varden migrating upstream into Cache Creek, and
- (2) that although confidence intervals were wide, mark-recapture Petersen estimates of Dolly Varden at Fish Hole were feasible and results were reasonably consistent between years.

In 1986, the decision was made to suspend further investigations on the Big Fish River Dolly Varden stock until 1991, at which time it would be re-assessed to determine the extent of the recovery following the five-year closure of the fishery.

In 1991, a deflection-board or "floating" weir, similar to the one used at the Babbage River in 1990-1992 (Sandstrom et al. 1997), was used to enumerate the upstream run of Dolly Varden in Cache Creek (Fig. 2). Unlike the rigid conduit-pipe weir, the deflection-board weir was

designed to rise and fall with the changes in water levels. This weir was installed at the previous weir site on Cache Creek on 28 July 1991, and removed on 18 September 1991. Although the weir remained intact for the duration of the study, it was under water for all or part of 28 days during the period of operation (Fig. 3). A total of 1617 upstream migrant Dolly Varden were counted at the weir in 1991.

In 1991, Petersen estimates were also possible using tag recapture information from tags applied to fish at the weir and recaptured at the Fish Hole during fall sampling. One estimate was done using the ratio of tagged to untagged anadromous Dolly Varden collected by seine net from the pools along the spawning and over-wintering site. This method yielded an estimate for the anadromous component of the stock of 2840 fish (95% CI 2014-3666) (Appendix III).

A second approach was used in 1991 to visually enumerate the fish. This involved one person in a dry suit snorkelling down the 2-3 km length of the over-wintering/spawning site, and counting the Dolly Varden individually and directly. While these counts do not provide an estimate of overall stock size, they provide a relative index of abundance of adult (e.g., >400 mm) Dolly Varden at the site. Direct counts were made of the Dolly Varden and the number of tags seen. This method yielded a partial count of the anadromous component of 2232 fish (95% CI 1716-2748) (Appendix IV).

An estimate of anadromous stock size was also done using data collected in 1994 (tags were applied at the over-wintering site in 1993 and recaptured there in 1994). Because this estimate was calculated with data collected over a period of approximately one year, tag loss and immigration was accounted for in the calculation. This work yielded an estimate of the size of the anadromous stock in 1994 of 4477 (95% CI 2305-6649) (Appendix V).

Visual counts of the number of adult anadromous Dolly Varden (primarily spawners) at the Fish Hole were also done in late September or early October of 1992 and 1993. The results of these counts indicate the number of adult Dolly Varden remained relatively stable between 1992 (656 counted) and 1993 (946

counted). Between-year differences in the counts may have been caused, at least in part, by differences in lighting conditions encountered.

While the confidence intervals are broad (Appendices I-V), the estimates for the 1987-1988 period are all within the range of 6000 to 9000 fish, whereas the estimates for 1991-1994 are considerably lower (range from 2000 to 5000). Smolts (first time sea-run migrants, or "small silvers") were integrated into the 1987 estimate, but only accounted for a small proportion of the 1991 and 1994 estimates. This could explain, at least in part, the discrepancy between stock size estimates for these two time periods.

Length and Age

Differences in the length frequency distributions of the anadromous component of the Big Fish River Dolly Varden stock are evident between 1984 and 1994 (Fig. 4). While the weir enumerations in 1987 and 1988 caught primarily fish smaller than 420 mm (97.8% and 69.2%, respectively), a greater percentage of the catch from the 1991 weir was made up of Dolly Varden >420 mm (73.8%). This may be due, at least in part, to the 1987 and 1988 weir studies being incomplete due to washout of the weirs. However, it may also be due to an increase in the number of larger fish, since the stock was not fished to any great extent since 1987. Data on the mean length of spawning males and females collected from the spawning site in the fall of 1984, 1986, and 1991 to 1994 also suggest that there has been an increase of 40 to 50 mm in length. In addition, it appears there has been a stabilization of the mean length of Dolly Varden in this system (Table 4).

The length-frequency distribution of Dolly Varden caught at the Babbage River weir studies (1990-1992, Sandstrom et al. 1997) are similar to that from the Big Fish River weir study (1991, Harwood unpubl. data) (Fig. 5). The bimodal distributions peaked at 270-280 mm and 490-500 mm at the Babbage River and 300-310 mm and 480-490 at the Big Fish River. The most noticeable difference between the Babbage and Big Fish length-frequency distributions was that there were comparatively

fewer large fish at the Big Fish River, with the right side of the curve being largely steeper representing less fish in these larger size categories (Fig. 5). The mean age of Dolly Varden female spawners also increased during the same period (e.g., in 1988, mean age was 5.4 years, standard deviation (sd) 1.47, $n = 26$; in 1991, mean age was 7.2, sd 1.45, $n = 61$). The maximum age recorded for a Dolly Varden in the Big Fish River system is 14 years ($n=2$), but few live past 10 years. Of 618 Dolly Varden examined since 1980 that were aged 5 years or older, only 3% of these ($n=18$) were older than 10 years of age.

In the neighbouring Babbage River (an essentially unexploited stock), the mean length of spawning female Dolly Varden was found to remain constant at 480 mm during the three season weir study (480 mm, 1990, $n=31$; 1991, $n=53$; 1992, $n=66$; Sandstrom et al., 1997). Furthermore, they were also larger at a given age than adult female Dolly Varden from the Big Fish River (Figure 6). The smaller mean size of adult female spawners in the Big Fish River may be due in part to an earlier age of first maturation.

Age at First Maturation

Due to the difficulties in ageing Dolly Varden and the small number of females that were sacrificed and sampled annually in the 325-450 mm size classes, it was not possible to accurately determine the percentage of females maturing at a given age (i.e., in order to calculate the age at first maturation). However, it appears that the proportion of females that mature in the smaller size classes (and presumably younger ages) is considerably higher in the Big Fish River (Fig. 7) than in other North Slope Dolly Varden stocks like those in the Babbage and Rat rivers (Figs. 8-9).

A random sample of 60 smolts was taken during seining surveys at the Fish Hole in 1991 and 1994. The majority of juvenile Dolly Varden from this system first go to sea at age 3 (3% at 2 years, 70% at age 3, 27% at age 4). Since smolts average 286 mm at age 3 yr, and exhibited a growth rate of 74 mm during the summer at sea (Table 5), then the majority of Dolly Varden in the 375-399 mm size class in

Fig. 7 must have been at least five years of age.

In the Big Fish River, 52-56% of Dolly Varden in the 375-399 mm size class in 1991 and 1994 were current-year spawners (Fig. 7). At the Babbage River, a smaller percentage of fish in this size class were current year-spawners (30% in 1991; 40% in 1992) of the female Dolly Varden in the 375-399 mm size class. In the next size class of 400-424 mm, 25% (1991) to 50% (1992) were current year spawners (Fig. 8). In 1991, most females appeared to be mature at a length >400mm, and in 1994, at a length >450mm (Fig. 7). This would put the age of 100% maturity at about 5-7 years (Fig. 6).

In contrast, a smaller percentage of the Babbage River females spawn in their fifth year, with the majority delaying spawning until their sixth year, if not later. Bain (1974) determined that over 50% of the anadromous females from the Babbage River matured at age 6 and that this was the age at which most females spawned for the first time in this system.

It is likely that the earlier stage of age of maturation seen in the Big Fish River females compared with the Babbage River females is due to the former being in a recovery phase. In growing populations, such as one recovering from decreased stock abundance, natural selection will push the age-of-first maturation to the physiological minimum. The sooner the individual fish are capable of reproducing, the sooner they can contribute offspring to the population. This is a possible explanation as to why the Big Fish River females mature at a younger age than Babbage River females.

Life History Stage Composition

The life history composition of the anadromous stock, determined by the various studies since the closure of the fishery, is summarized in Fig. 10. Small, pre-reproductive Dolly Varden are called "small silvers". Current year spawners appear in spawning colouration. Non-spawning adults in a resting phase are called "adult silvers" (or "large silvers"). Non-spawning (silver) adults, typical of other Dolly Varden populations, have not been found in significant numbers in the Big Fish River stock,

in comparison with other North Slope Dolly Varden stocks. Adult silvers are common in the neighbouring river systems like the Babbage and Rat rivers (e.g., mean = 32% of the Babbage River dead sample at the 1990-1992 weirs, Sandstrom et al. 1997; mean = 69.4% of the 1995-2001 Rat River summer subsistence fishery, Harwood 2002). They have also been observed in large numbers in the Firth River (Glova and McCart 1974). The 1991 weir enumeration on the Big Fish River was likely the best opportunity to document the presence of this life history stage due to the length of time that the weir operated. However, the majority (94%) of silvers enumerated were small (less than 420 mm) immature Dolly Varden, probably first- and second-time searun migrants.

In the late fall of 1991, visual and seining surveys done at the Fish Hole also failed to detect the presence of adult silvers in appreciable numbers. Although studies done in the fall at spawning and over-wintering sites tend to target the spawning component of the population, adult silvers were captured (25 % of the catch, $n = 472$) in an identical fall survey done at the Rat River over-wintering site in 1995 (Harwood, L., Sandstrom, S., unpubl. data). The most plausible explanation for the absence of adult silvers in the Big Fish River is that Dolly Varden in this system spawn sequentially once they reach maturity and thus, unlike other stocks, large numbers of adult silvers are not evident.

Sequential Spawning

The percentage of mature female Dolly Varden, by length group, differs considerably when the Big Fish River Dolly Varden stock (Fig. 7) is compared with the Babbage River (Fig. 8) and Rat River (Fig. 9) stocks. Whereas non-spawning female Dolly Varden make up a considerable proportion of each size class over the entire size range (350-575 mm) of Dolly Varden caught at the Rat and Babbage rivers, non-spawning females in the Big Fish River population were limited primarily to the 325-449 mm size classes. The apparent absence of current-year non-spawning females (e.g., large silvers) >425 mm in fork length in the Big Fish River suggests that some, perhaps the majority, of the females from this system spawn every

year after they mature at about 375-425 mm in length. Tag returns from the Fish Hole support this conclusion. All recaptures ($n = 11$) of Dolly Varden tagged at the Fish Hole in 1993 as spawners, were caught again at the Fish Hole in spawning condition in 1994. It is not understood how the majority of Dolly Varden in the Big Fish River are able to spawn in successive years, but this may be due to the combination of an earlier, thus longer, access to coastal food resources, and a shorter freshwater migration distance (i.e., decreased energy requirements) compared with systems more distant from the ocean (i.e., Rat River).

Growth

Growth rates of Dolly Varden in the Big Fish River were determined from recapture of tagged individuals, caught approximately one year after the application of the tag (Table 5). These data show that for juvenile (smolts) Dolly Varden (300-350 mm in the fall), mean annual growth over the following year was 74 mm. This decreases to 34 mm/year for the smaller spawners (400-450 mm), and to 11 mm/year for the larger spawners (i.e., >500 mm). The growth rate of adult female Dolly Varden was not significantly different between the Babbage, Big Fish and Rat rivers (Fig. 6).

Fecundity and Egg Diameter

The average mean fecundity, adjusted for fork length, for the Big Fish River stock did not vary between 1991 (2329 eggs, $n = 63$) and 1993 (2313 eggs, $n = 28$) (Sandstrom 1995). However, mean fecundity (adjusted for the size of the fish) was significantly higher (by 500 eggs) for Babbage River females than for Big Fish River females. For example, a 475-mm spawning female from the Big Fish River had, on average, 500 fewer eggs than a 475-mm spawning female from the Babbage River. This difference is due to females in the Big Fish River having larger mean egg diameters (by 0.5 mm or 30 % by volume) and consequently lower fecundities than females in the Babbage River (Fig. 11). That is, if egg size and egg number (fecundity) are negatively correlated, thus larger eggs in Big Fish River females means fewer numbers can be accommodated in the body cavity.

Glova and McCart (1974) reported an egg diameter in female Dolly Varden from the Firth River similar to that observed in females from the Babbage River. Sandstrom (1995) speculated that the larger adjusted mean egg diameter found in Big Fish River females compensates for the higher and more variable incubation temperatures experienced by eggs in this system. Water temperatures at groundwater spring source are 16° C at Cache Creek/Big Fish in 1973 (McCart and Bain 1974) and in 1992 (Sandstrom 1995), and 4° C at the Babbage River in 1972 (McCart and Bain 1974) and 1993 (Sandstrom 1995).

Females from the Big Fish River showed a significant positive correlation between egg diameter and body length, whereas females from the Babbage River did not (Fig. 11). Bain (1974) found no correlation between egg diameter and fork length in spawning females from the Babbage River stock. It is unclear why the smaller females in the Big Fish River appear to produce eggs with smaller, perhaps less optimal, diameters than larger females in this system. It may be that only large females can successfully produce, accommodate, and extrude large diameter eggs. Incubation times may be longer with larger eggs also.

Sex Ratios

The proportion of anadromous male Dolly Varden in the 1984-1994 studies ranged from 9-18% (18% in 1984, 14% in 1987, 17% in 1988, 11% in 1991, 14% in 1993 and 9% in 1994). On average, males constitute only 14% of all the spawning anadromous Dolly Varden sampled, resulting in a female to male ratio of 6:1 for the Big Fish River system. This skewed sex ratio is similar to that found within the Rat River Dolly Varden stock, another stock that has been (and continues to be) subjected to considerable fishing pressures. In comparison, anadromous males were observed to comprise between 40-48% of the spawners in the Babbage River 1990 to 1992 (Sandstrom et al. 1997) and Firth River (Glova and McCart 1974), both of which are essentially unexploited stocks.

Large numbers of resident male Dolly Varden (small, non-anadromous "sneak spawners") are

found at the spawning site in the Big Fish River, which suggests that the relative absence of large anadromous males may be due to a greater rate of precocious maturation in the stock. It is not known why more males mature into resident males than anadromous males, but this is common particularly in the Big Fish River. The sex ratio for anadromous charr in the Rat River is also skewed toward females. This may reflect a trait that is passed on genetically, and/or a response to past fishing pressure.

Sex ratios of anadromous stock that receive little fishing pressure tend to be less disproportionate than those that do. For this reason, fishing pressure may cause or contribute to a shift in the life history strategy of male Dolly Varden of the Big Fish River. Fishing tends to eliminate anadromous males, as they are more readily caught in the nets by their type. If there is a genetic basis for residency vs anadromy, fishing would tend to drive the population toward non-anadromy. At the same time, however, fishing also lowers population abundance, which lessens pressure on the over-wintering and early summer freshwater habitats. This in turn increases survival of resident males and/or juveniles. If growth is limited, lower population size likely means better and faster growth, which in turn would foster the increase of resident males.

CHANGES IN THE FRESHWATER HABITAT

It is likely that natural changes in the habitat at the Fish Hole have had an impact on the Big Fish River Dolly Varden stock. Elders from Aklavik (J. Archie, D. A. Gordon, pers. comms., 1990) report that, compared with water levels at the Fish Hole in the 1960's and 1970's, present day water levels in winter are much lower than they were in the 1960's and 1970's. They also report that there are fewer pools, and those that are present are shallower. They also report that the taste of the water and amount of visible algae have also changed over this time period.

J. Archie (pers. comm., 1994) speculated that a small earthquake experienced in the Aklavik area in the mid-1980's might have changed the geology around the Fish Hole and reduced the volume of groundwater discharged to the site.

Unfortunately, there are no long-term data on discharge volumes against which to make comparisons to confirm this. However, there is physical evidence of geological disturbances in the area at the sites of groundwater flow.

Elders have observed that a large section of limestone cliff, just above the main waterfall, collapsed into the stream some time in the late 1970s or early 1980s. Mutch and McCart (1974) located a fault line immediately to the south of the waterfall at the Fish Hole in the area of the groundwater discharge. Based on the high temperatures, low dissolved oxygen, and high dissolved solids in the groundwater flow to the Fish Hole, they speculated that the groundwater likely originated from great depth and possibly within this fault. Clark et al. (2001) documented three sources of groundwater to the Cache Creek site, one of which originates from a deep sub-permafrost level.

It is conceivable that groundwater flow could have been affected if there was movement within the fault area. Geological Survey of Canada records of seismic activity are available as far back as 1970, and these indicate that 1981, 1983 and 1986 were years of greater than average seismic activity in the northern portion of the Richardson Mountains. There were five, nine and five events recorded in those years, respectively. For the other years on record, there was an average of two events per year (range 0 to 4). The error associated with the calculation of the epicentre is between 10% and 20% of the distance between the event and the recording station (R. Wetmiller, Geological Survey of Canada, 1997, pers. comm.). The spawning and over-wintering site on the Big Fish River is located approximately 100 km from Inuvik. Using an error of 10 to 20 km associated with events in the general area of the spawning and over-wintering site, records indicate that there have been four seismic events within 20 km of the spawning and over-wintering site since 1970 (Table 6). All of these occurred in the late 1970's and early 1980's.

These seismic records lend some support to the hypothesis that there may have been some geological change in the region of the spawning and over-wintering site in the early 1980s, which in turn may have resulted in a decrease in the volume of groundwater discharged to the

site. The effect of this would be a reduction in the amount of over-wintering habitat and thus the number of anadromous Dolly Varden that the site could sustain.

A decrease in the volume of groundwater discharging at the spawning and over-wintering site on the Big Fish River could also have another damaging effect on the stock in addition to the above noted loss of habitat. Unlike other North Slope Dolly Varden systems like the Babbage River where spawning occurs on or near the groundwater discharge area (i.e., eggs are exposed to relatively constant incubation temperature), Dolly Varden in the Big Fish River spawn approximately 2 km downstream of the discharge area. This is thought to be due to the high water temperatures at the discharge site. During winter, as the water flows downstream away from the discharge area, its temperature drops until finally it reaches a point downstream where it freezes. If the stream is shallower now during the winter than it was in the late 1970s and early 1980s, the temperature of the water on the spawning beds would be less stable and fluctuate with air temperature. This in turn could compromise hatching success.

SUMMARY

The Big Fish River Dolly Varden stock is characterized naturally by a number of life history traits, which collectively contribute to the apparent low reproductive capacity of this stock. This in turn would be expected to limit the ability of the stock to sustain a fishery. Some of these are:

1. The low numbers of spawning anadromous males in the Big Fish River have not only a significant negative effect on the overall reproductive potential of the stock, but also represent a considerable loss of biomass to the fishery.
2. Spawning Dolly Varden are more susceptible to capture in comparison to non-spawning males, both at the mouth of the river and at the spawning and over-wintering site. Thus, spawners are the primary target of the fishery, reducing the long term sustainability of the stock.

3. The lower size-related fecundity in female Dolly Varden in the Big Fish River, in comparison to those in other neighbouring systems, results in fewer Dolly Varden being produced by each male/female pairing. This lowers the reproductive potential of the population.
4. If the larger eggs of large females are better adapted for the higher and more variable incubation temperatures in this system, then the annual reproductive potential of the stock is likely disproportionately further reduced by the selective removal of these large fish by a gillnet fishery.

Although the Big Fish River Dolly Varden stock has shown signs of recovery in terms of its length and age composition since the closure of the fishery, overall abundance remains well below historic levels. Reasons for this are not fully understood, but likely include physical changes to the spawning and over-wintering habitat on Cache Creek that may be limiting the size of the stock.

The present estimated harvest of approximately 100 Big Fish River Dolly Varden in the Shingle Point fishery represents 4-9% of the 1991 and 1993 Petersen estimates of stock size. This is considered to be a safe recommended harvest level based on experience with Arctic charr stocks which suggest a take of 10% is sustainable. A small fishery at the coast or mouth of the river which targets Big Fish River fish (e.g., catch of 200 or less annually in total) should be within this amount, sustainable and a means to continue to provide information on the status of the stock. However, taking into consideration the problems discussed above, it is recommended that the harvest of Dolly Varden from the Big Fish River not be allowed to exceed this level. As well, it is recommended that fishing should not take place at the Fish Hole spawning and over-wintering site. Periodic, recent high levels of harvest (i.e., 805 harvested in 1996, Table 1) likely contributed to the continued depression of the stock.

The first step towards understanding this situation more fully is to evaluate whether a habitat related problem is circumventing the recovery of this stock, and which of the Dolly

Varden life history stages is being affected to the greatest extent. For example, future research should determine whether the problem lies in the loss of over-wintering habitat for adult Dolly Varden, and/or whether an unstable incubation environment imposes a greater mortality on incubating eggs. Both of these aspects may be limiting stock size.

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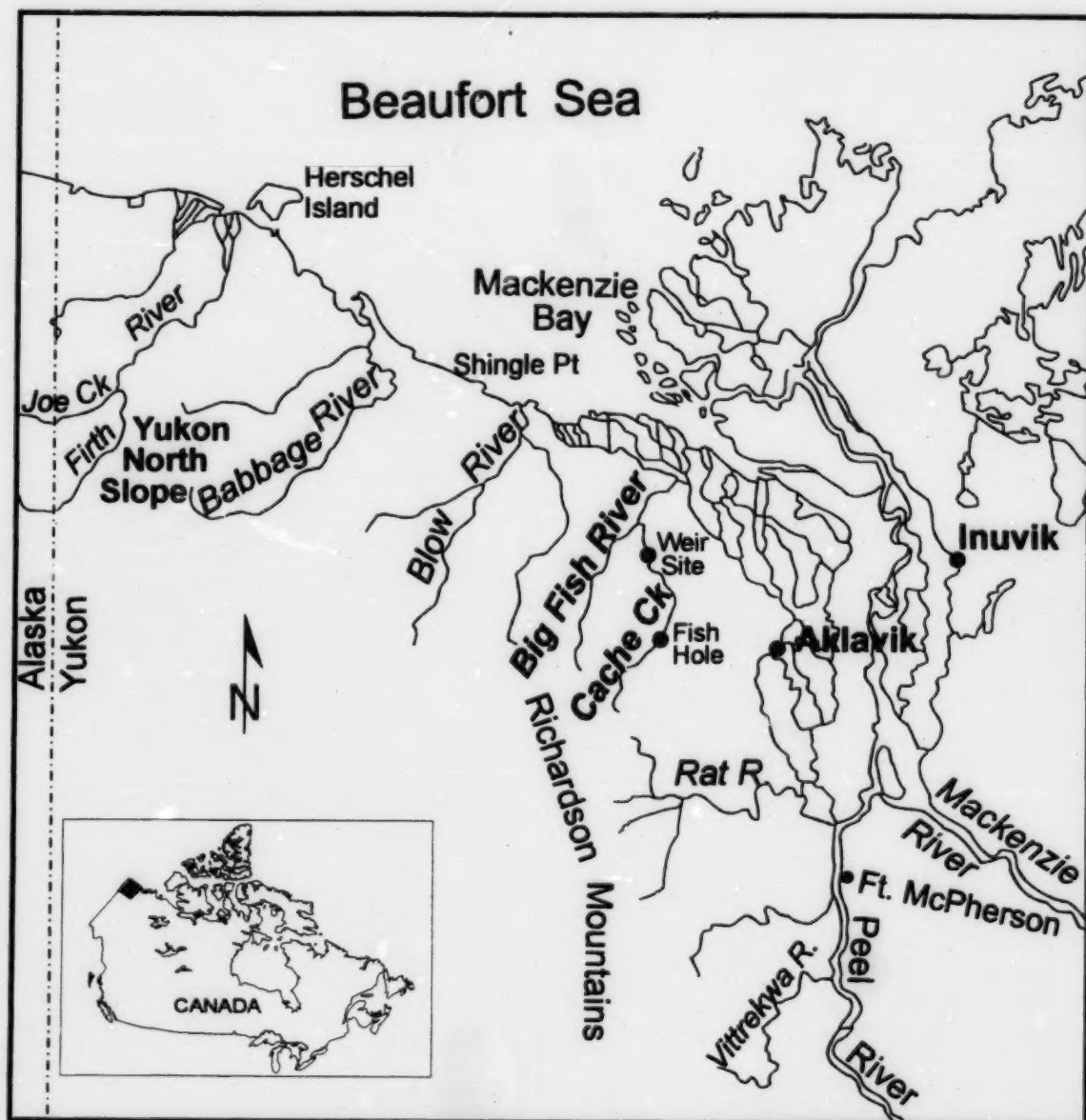


Fig. 1. Yukon North Slope showing sampling sites on the Big Fish River.

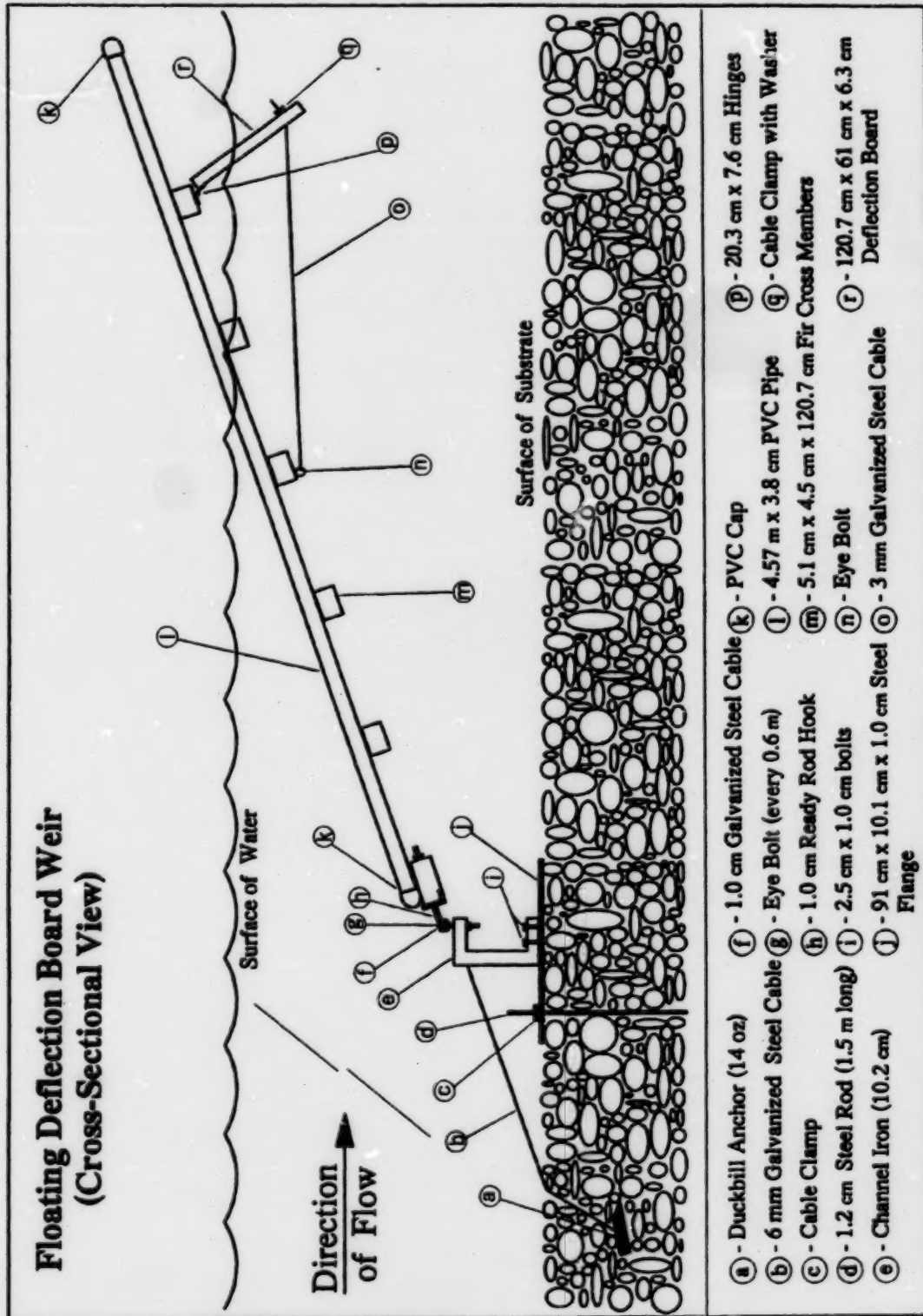


Figure 2. Diagram showing a floating deflection board weir system.

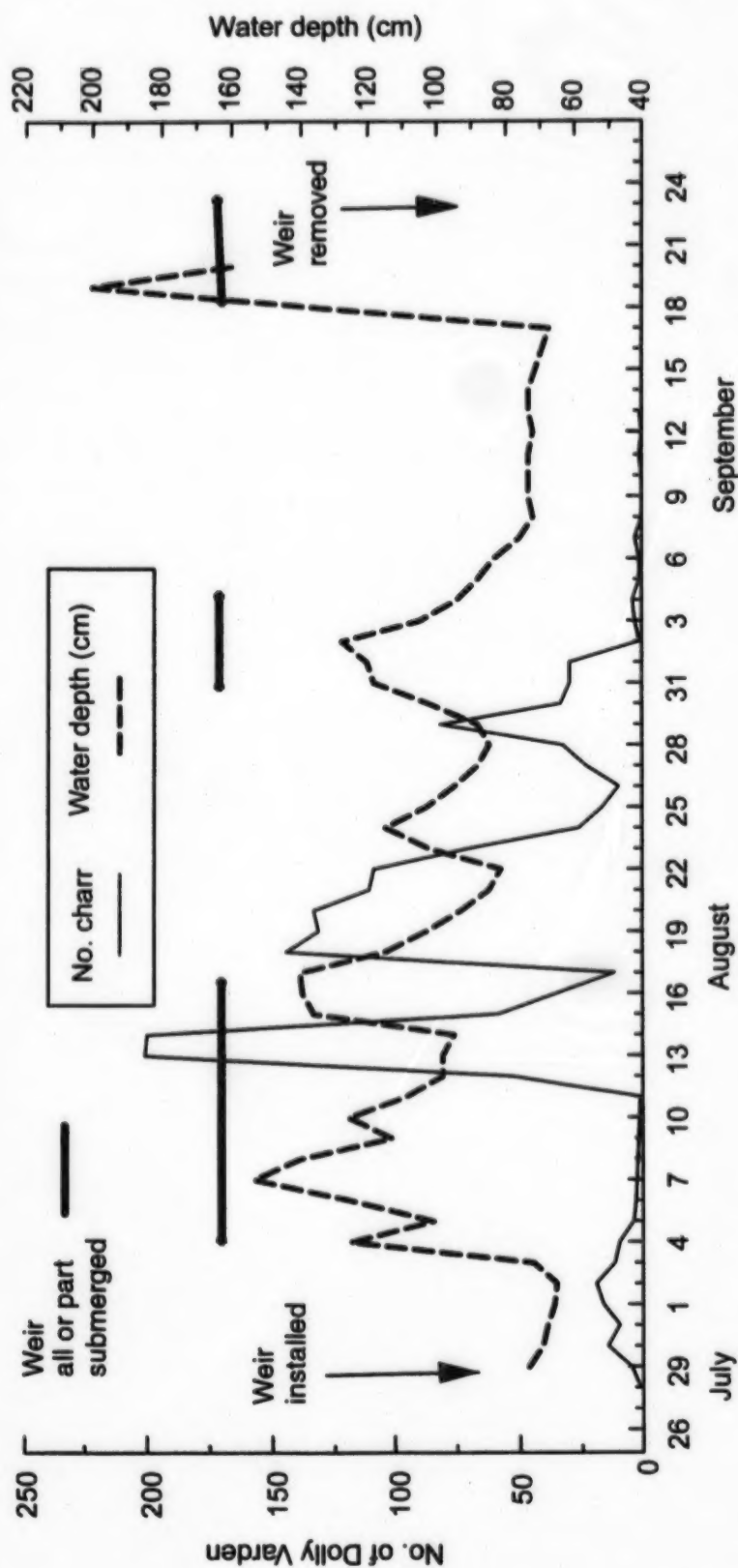


Figure 3. Dates of operation of the deflection-board weir at Cache Creek, NT, July-September 1991.

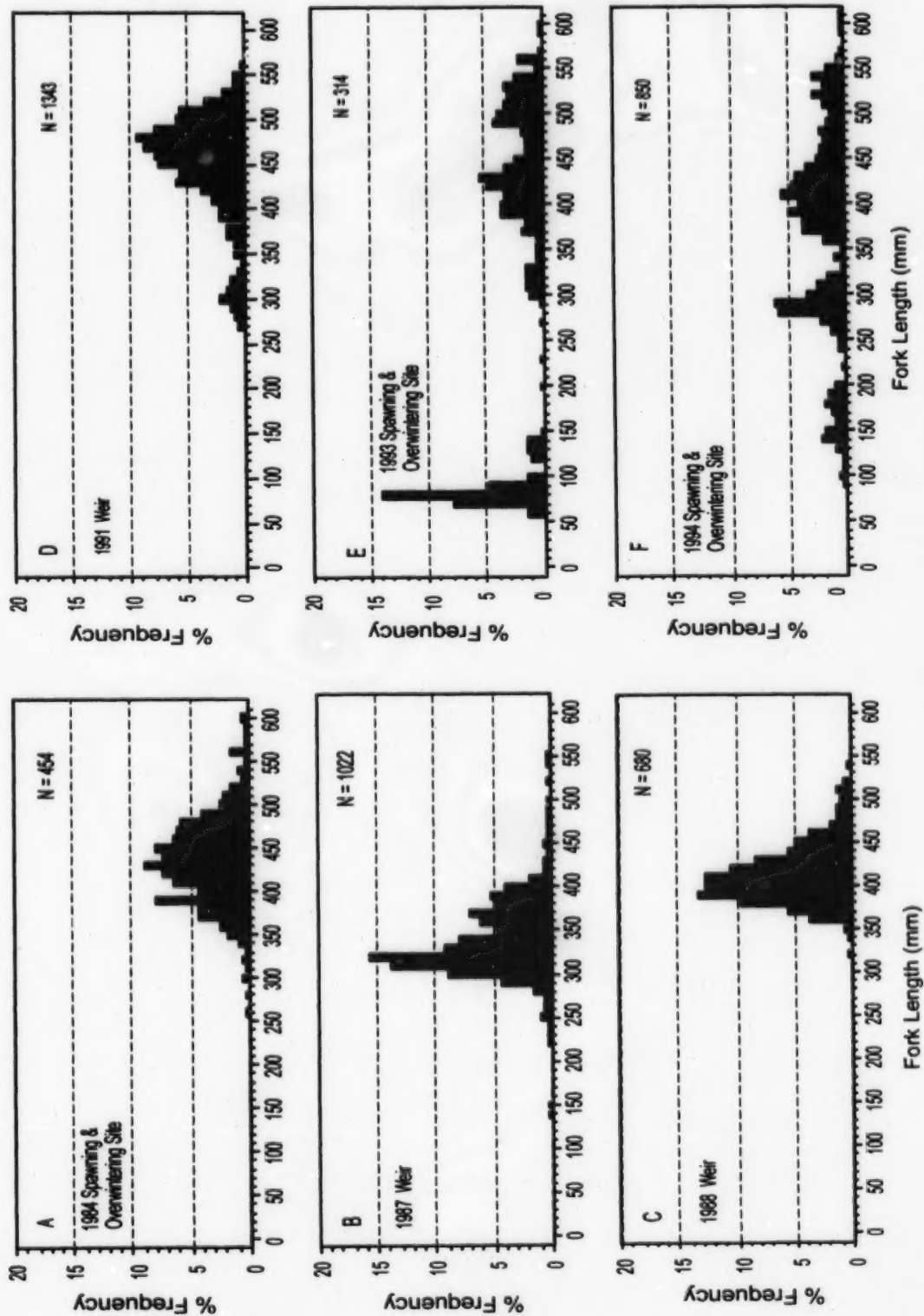


Figure 4. Length-frequency distributions of Dolly Varden from Cache Creek (Fish Hole) spawning grounds surveys (1984, 1993 and 1994) and weir enumerations (1987, 1988 and 1991).

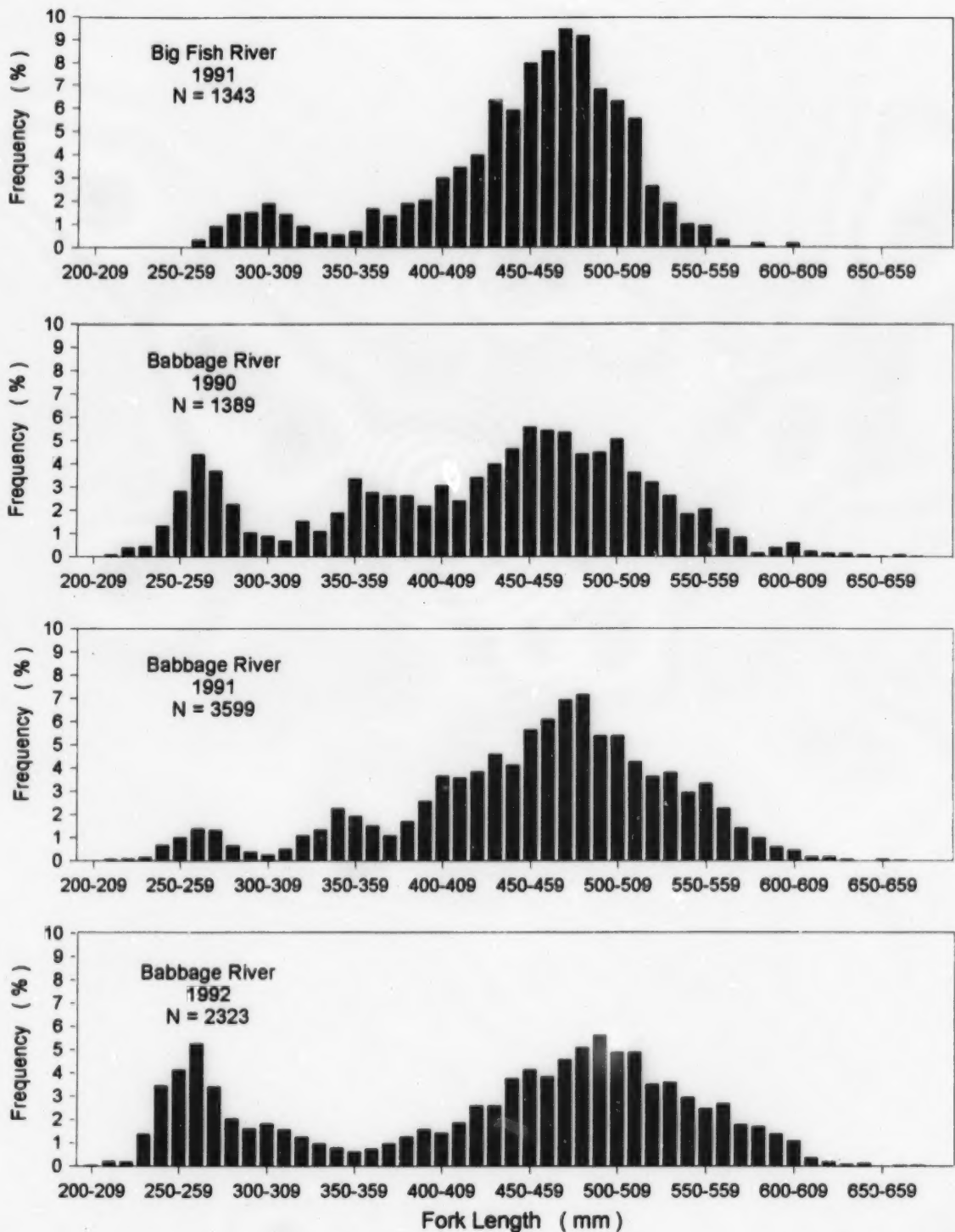


Figure 5. Length-frequency distributions of Dolly Varden at the 1990-1992 Babbage River weirs and the 1991 Big Fish River weir. (Distributions do not include the resident male life history stage).

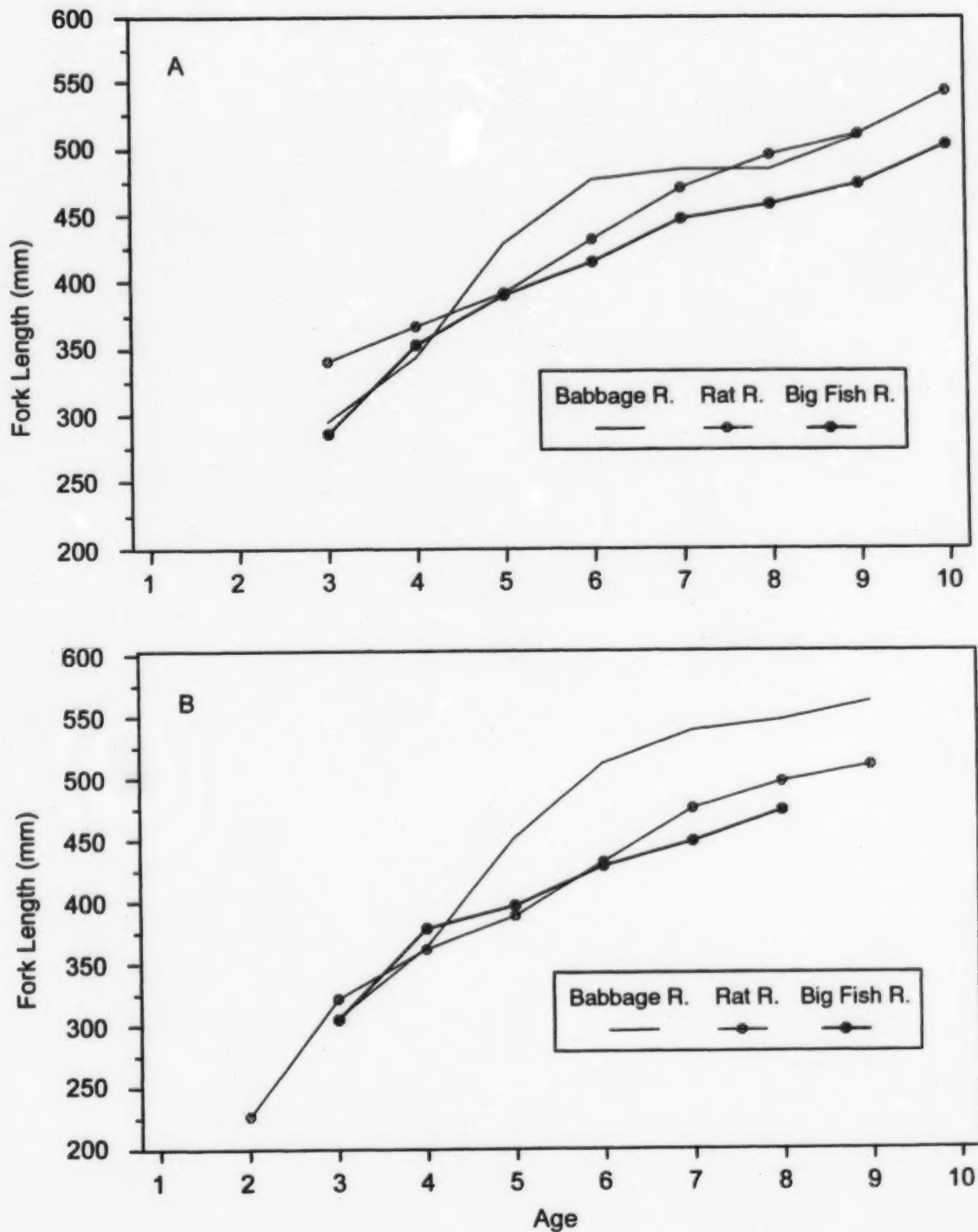


Figure 6. Mean fork length-at-age for females (A) and males (B) from three stocks of Dolly Varden from the Yukon North Slope area of western Canada (data from Sandstrom 1995; Harwood 2002).

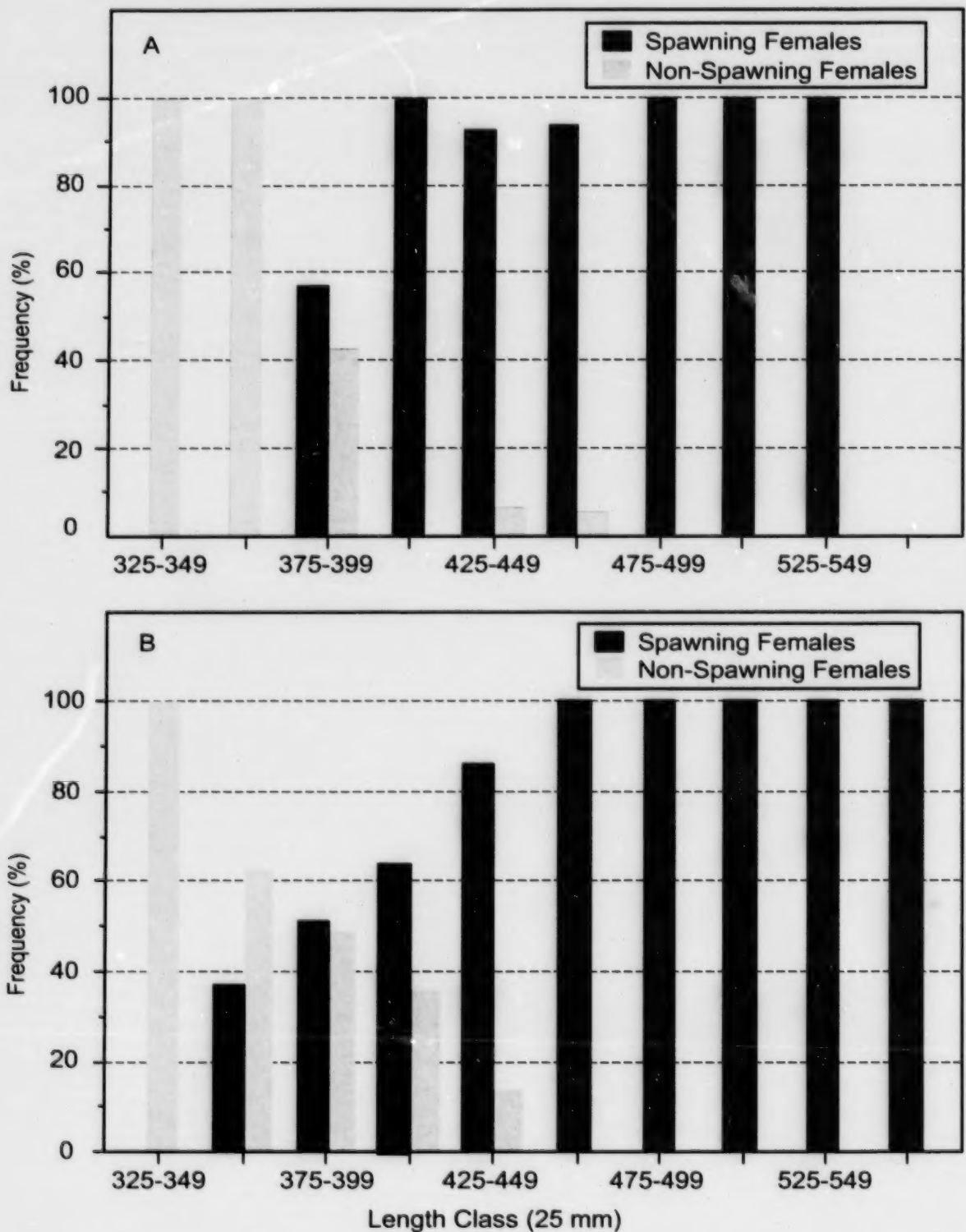


Figure 7. Maturity frequency of female Dolly Varden, by 25mm size classes, recorded in 1991 (A) and 1994 (B) at the Big Fish River.

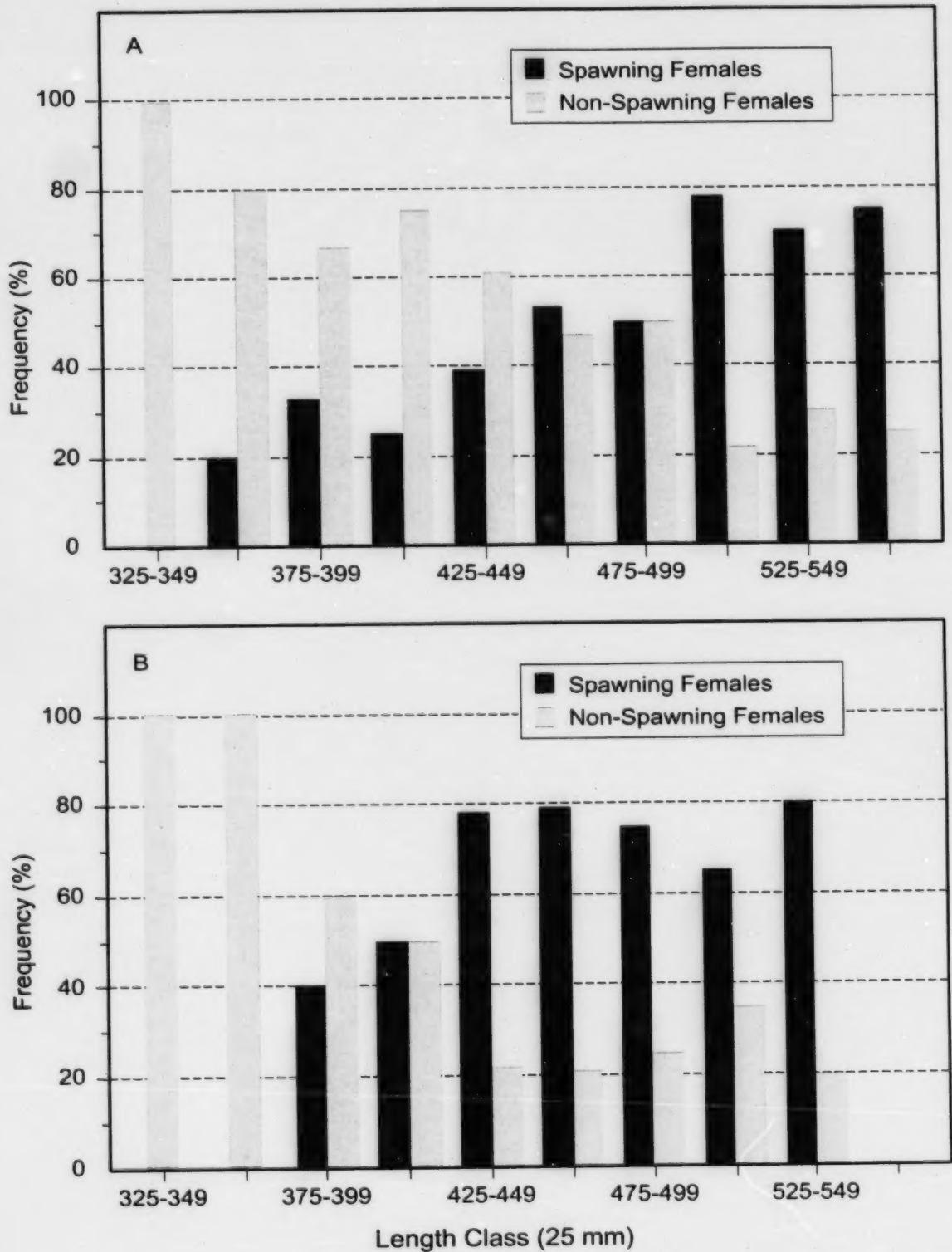


Figure 8. Maturity frequency of female Dolly Varden, by 25 mm size classes, recorded in 1991 (A) and 1992 (B) at the Babbage River (Sandstrom 1995).

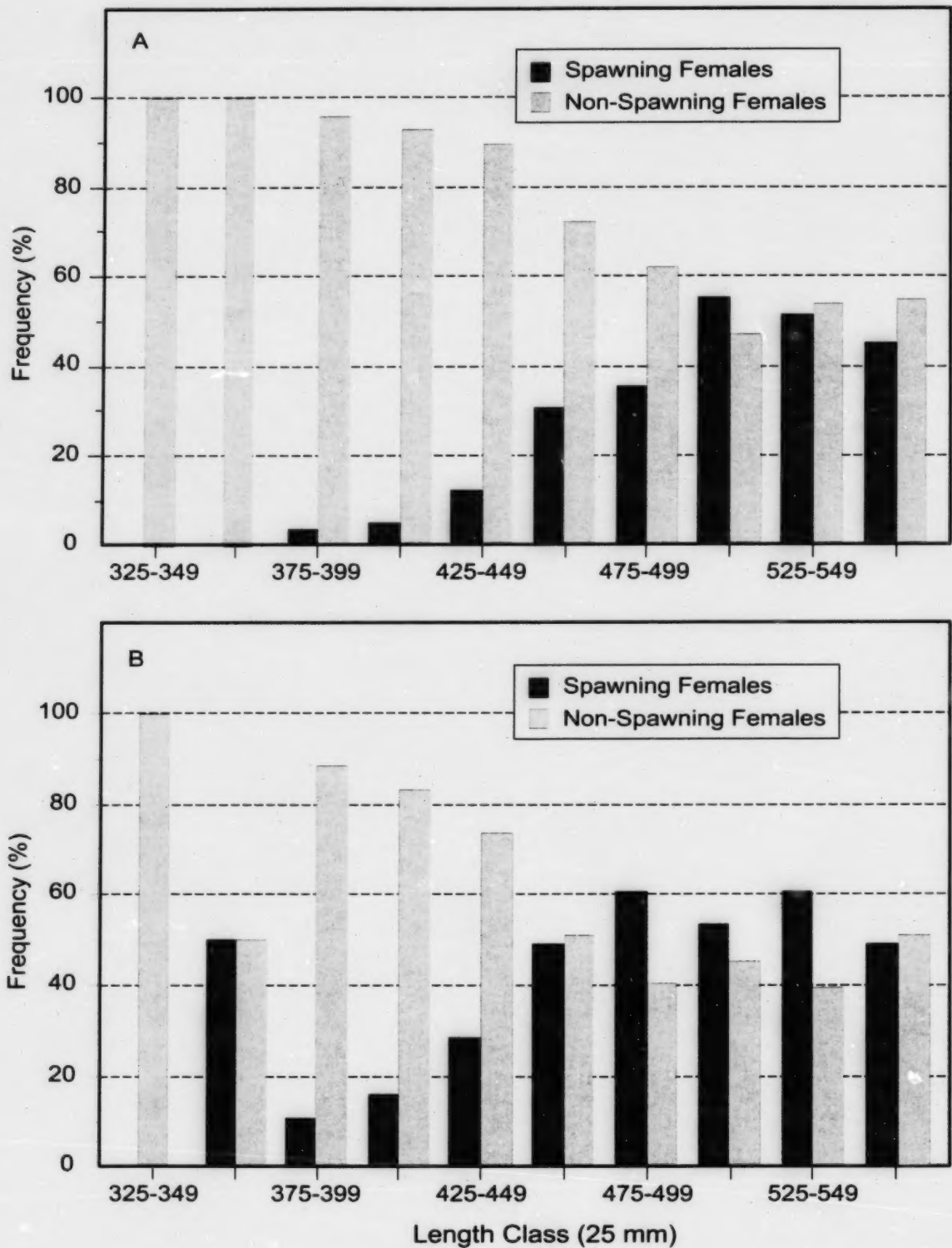


Figure 9. Maturity frequency of female Dolly Varden, by 25 mm size classes, recorded in 1995 (A) and 1996 (B) at the Rat River (Harwood 2002).

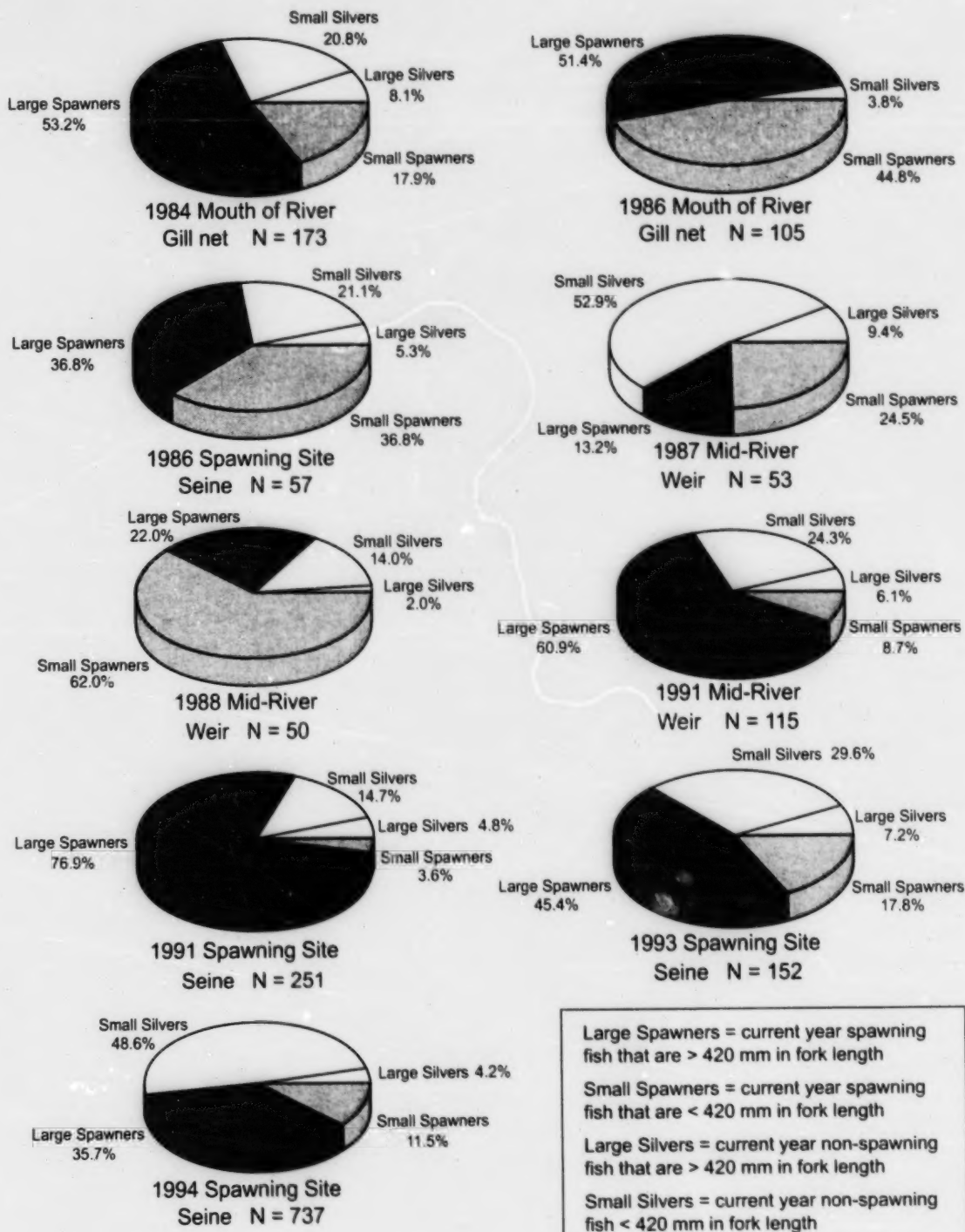


Figure 10. Maturity composition of biological samples of anadromous Dolly Varden collected from the Big Fish River. (For samples taken at weir, only dead sampled fish were used in the calculations as maturity cannot be accurately assigned based on external examination of live sampled fish).

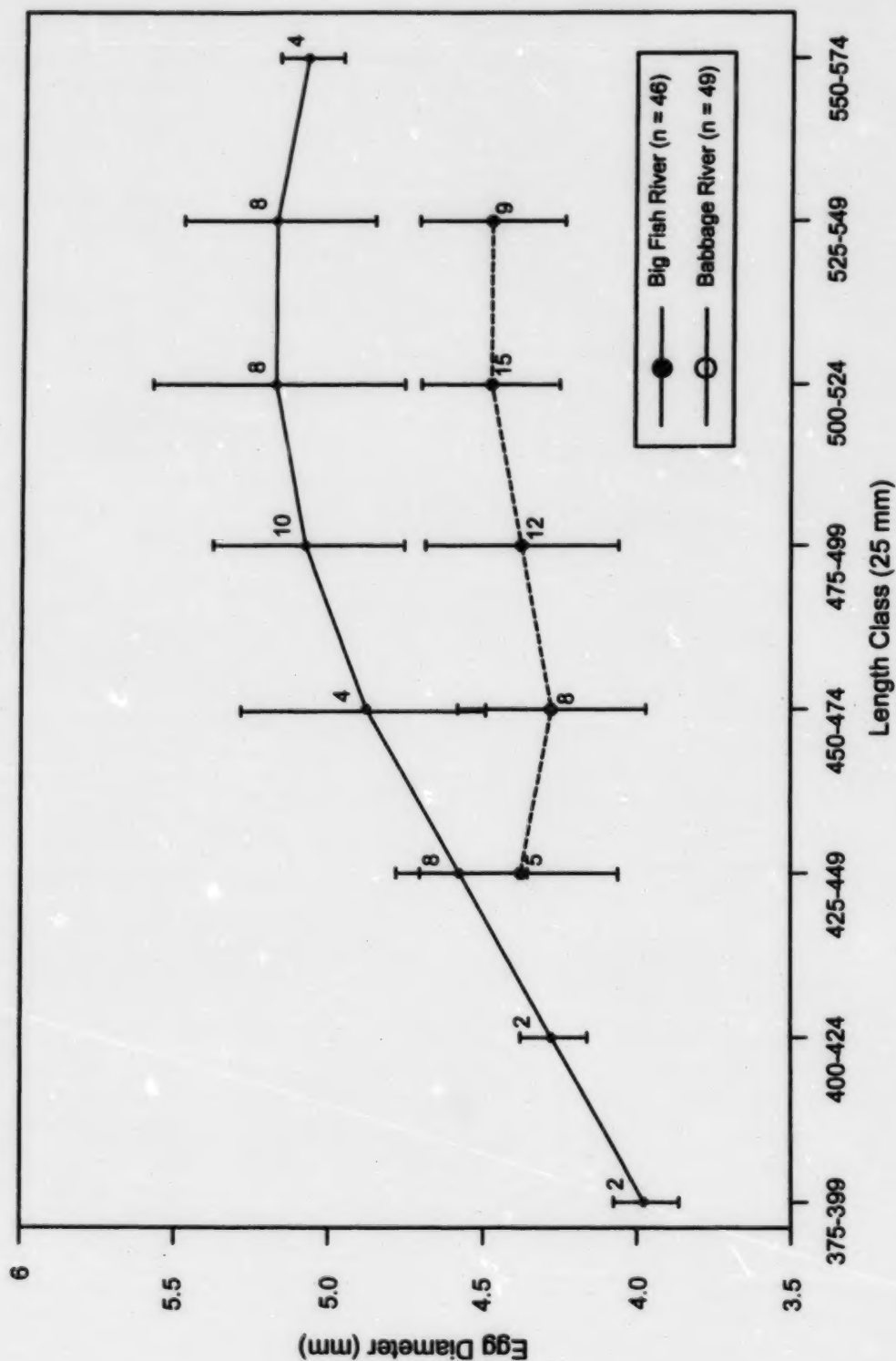


Figure 11. Relationship of mean terminal egg diameter (+ 1 standard deviation) and fork length for mature female Dolly Varden (grouped by 25 mm size classes) collected in 1993 from the Babbage (Sandstrom 1995) and Big Fish River (Harwood unpubl. data) stocks. (Numbers by each mean represent sample sizes for the length classes.)

Table 1. Dolly Varden harvests at Shingle Point, King Point and Herschel Island as reported to the Inuvialuit Harvest Study field workers, 1988 – 1999.

Year	Shingle Point	King Point	Herschel Island	Annual Total
1988	147	50	55	252
1989	30	75	25	130
1990	214	0	0	214
1991	7	0	30	37
1992	17	24	0	41
1993	119	0	19	138
1994	33	52	130	215
1995	63	0	48	111
1996	805	0	560	1365
1997	124	0	130	254
1998	521	0	233	754
1999	250	0	0	250

Data sources: (Fabijan 1991a,b,c; Fabijan 1995a,b,c,d; Fabijan 1997a,b; Fabijan 1998; Stephenson 2000)

Table 2. Summary of biological collections of Dolly Varden from the Big Fish River, Northwest Territories, 1980 - 1994.

Year	Collection Location	Purpose of Collection	Date of Collection day/month	No. Live Sampled (no. tagged)	No. Dead Sampled	Total No. Sampled	Publication/Report
1980	mouth	Monitor Composition of Catch	20/08 to 21/08	-	94	94	Unpublished Data
1982	Fish Hole	Document Infectious Pancreatic Necrosis	00/09	-	10	10	Can. Tech. Rep. Fish. Aquat. Sci. 1441: 11 p.
1984	mouth	Monitor Composition of Catch	10/08 to 24/08	-	192	192	NOGAP Project 2-109: 57 pp.
1984	Fish Hole	Study Composition Dynamics	04/09 to 09/09	455 (444)	-	455	NOGAP Project 2-109: 57 pp.
1986	mouth	Monitor Composition of Catch	15/08 to 19/08	-	105	105	Fisheries Joint Management Committee Rpt.86-002
1986	Fish Hole	Genetic Analysis	28/09	-	76	76	Physiol. Ecol. Japan, Spec. Vol. 1: 405-420
1987	weir	Study Population Dynamics	13/08 to 02/09	1000 (597)	71	1071	North/South Consultant Report: 68 pp.
1988	weir	Study Population Dynamics	02/08 to 25/08	582 (178)	81	663	Fisheries Joint Management Committee Rpt.89-001
1988	all	Genetic Analysis	22/09	-	120	120	Reist, unpubl. data
1991	weir	Study Population Dynamics and Energetics	29/07 to 03/09	1237 (435)	115	1452	Harwood and Sandstrom, unpubl. Data
1991	Fish Hole	Study Population Dynamics	02/10 to 03/10	264	-	264	Harwood and Sandstrom, unpubl. Data
1992	Fish Hole	Genetics and Energetics	08/05	-	46	46	Sandstrom 1995
1992	mouth	Monitor Composition of Catch	10/08 to 27/08	-	23	23	Harwood and Sandstrom, unpubl. Data
1992	Fish Hole	Study Population Dynamics and Energetics	01/10	-	37	37	Sandstrom 1995
1993	Fish Hole	Genetics and Energetics	28/08	-	28	28	Sandstrom 1995
1993	Fish Hole	Study Population Dynamics and Energetics	30/09 to 01/10	260 (134)	72	332	Sandstrom 1995
1994	Fish Hole	Study Population Dynamics and Energetics	29/09	788 (285)	171	959	Harwood and Sandstrom, unpubl. Data

Table 3. Summary of abundance estimates for the anadromous component of the Big Fish River Dolly Varden stock using mark recapture data.

Year	Source	Tagging Location	Recapture Location	Stock Size Estimate
1973	Stein et al. (1973)	Gill net (mouth of river)	Gill net (mouth of river)	20,700
1973	Stein et al. (1973)	Gill net (mouth of river)	Gill net (overwintering site)	13,500
1985	Gillman (unpublished)	Seine (overwintering site)	Gill net (mouth of river)	4600
1987	MacDonell (1988)	Weir (lower river)	Seine (overwintering site)	9076
1988	Appendix 1	1987 Weir (lower river)	1988 Weir (lower river)	7379
1988	Fehr and Archie (1988)	Weir (lower river)	Seine (overwintering site)	8499
1988	Fehr and Archie (1988)	Seine (overwintering site)	Seine (overwintering site)	5827
1988	Appendix II	Weir 87 & 88 (lower river)	Seine (overwintering site)	6786
1991	Appendix III	Weir (lower river)	Seine (overwintering site)	2840
1991	Appendix IV	Weir (lower river)	Visual (overwintering site)	2232
1994	Appendix V	1983 Seine (overwintering site)	1984 Seine (overwintering site)	4477
				average 7509

Table 4. Mean fork length (± 1 standard deviation) of mature anadromous Dolly Varden sampled at the spawning site on the Big Fish River.

Year	Sex	Fork Length (mm)	Range (mm)	N
1984	Female	430 $\pm$ 42	342 to 575	355
	Male	440 $\pm$ 56	360 to 588	43
1986	Female	425 $\pm$ 35	368 to 528	39
	Male	456 $\pm$ 46	390 to 539	16
1991	Female	468 $\pm$ 30	392 to 554	152
	Male	499 $\pm$ 32	412 to 555	50
1992	Female	471 $\pm$ 33	375 to 551	59
1993	Female	468 $\pm$ 54	366 to 584	135
	Male	502 $\pm$ 61	408 to 601	17
1994	Female	461 $\pm$ 57	344 to 595	317
	Male	488 $\pm$ 67	370 to 606	30

Table 5. Mean annual growth of Dolly Varden in the Big Fish River calculated from floy-tagged fish recaptured approximately one year from date of initial tagging.*

Length Class	Mean Annual Growth	Standard Deviation	Sample Size
300 - 349 mm	74 mm/yr	± 20 mm	34
350 - 399 mm	50 mm/yr	± 13 mm	20
400 - 449 mm	34 mm/yr	± 14 mm	8
450 - 499 mm	20 mm/yr	± 12 mm	10
500 - 549 mm	11 mm/yr	± 4 mm	3

* For example, a charr between 300 mm and 350 mm in the fall is predicted to grow 74 mm ± 20 mm in length by the following fall.

Table 6. List of seismic events which occurred within 20 km of the spawning and overwintering site on the Big Fish River between 1970 and 1997. *

Year	Month	Day	Time	Lat.	Long.	Mag.	Depth
1977	04	05	04:09:21	68.23	136.66	3.4 ML	18
1977	04	10	18:38:49	68.15	136.22	3.2 MN	18
1980	01	25	07:15:24	08.22	130.12	2.0 ML	18
1983	10	22	08:22:35	68.17	136.23	2.1 ML	18

* Geological Survey of Canada, www.nrcan.gc.ca/gsc

Depth = focal depth in kms

Magnitude (Mag) is ML = Richter scale, MN = Nuttli scale

Appendix I

Size of the Anadromous Component in the Big Fish River Dolly Varden Stock, 1987

Using Mark Recapture Data and the Adjusted Peterson Estimate Controlled for the Effect of Recruitment

	Tagged	Collected*	1988 Recaptures
1987	599 (M)	-	-
1988	-	668 (> 360 mm) (C)	48 (R)

Anadromous Stock Size (according to Chapman, 1951):

N = Size of the population in 1987

$$N = \frac{(M + 1)(C + 1)}{R + 1} = \frac{(599 + 1)(668 + 1)}{48 + 1} = 8192$$

Sample Variance for Estimate of Stock Size (according to Chapman, 1951);

$V(N)$ = Sampling Variance

$$V(N) = \frac{N^2(C - R)}{(C + 1)(R + 2)} = \frac{8192^2(668 - 48)}{(668 + 1)(48 + 2)} = 1,243,871$$

$$\text{Standard Deviation} = \sqrt{V(N)} = \sqrt{1,243,871} = 1115$$

Estimated Stock Size in 1987 = 8192 ± 1115(68% confidence limit)

If we assume a similar tag loss frequency of 11.3% recorded for Dolly Varden charr (>150 mm) in southwestern Alaska (Armstrong, 1984), then the new estimate using $R = 53.4$ becomes:

Adj. Estimate of 1987 Stock Size = 7379 ± 950(68% confidence limit)

* To control for the effect of recruitment the smolt size classes (< 370 mm) were not included. The smolt life history stage (usually 3 years of age) is the first time the charr move to sea in the summer (i.e., point of recruitment to anadromous component).

Appendix II

Bailey's Estimator of Stock Size of Anadromous Dolly Varden in the Big Fish River Using Triple Mark Recapture Data

Year	Fish Newly Marked	Fish Examined	No. of 1990 Tag Recaps.	No. of 1991 Tag Recaps
1987	597 (M_1)	-	-	-
1988	178 (M_2)	1244 (C_2)	48 (R_{12})	-
1988 (fall)	-	925 (C_3)	22 (R_{13})	15 (R_{23})

Using Bailey's large sample formula (Bailey 1951):

N_2 = Estimate of Population Size in Interval 2 (i.e., 1991)

$$N_2 = \frac{(M_2)(C_2)(R_{13})}{(R_{12})(R_{23})} = \frac{(178)(1244)(22)}{(48)(15)} = 6766$$

$$\begin{aligned} \text{Var}(N_2) &= (N_2)^2 \left(\frac{1}{R_{12}} + \frac{1}{R_{23}} + \frac{1}{R_{13}} - \frac{1}{C_2} \right) \\ &= (6766)^2 \left(\frac{1}{48} + \frac{1}{15} + \frac{1}{22} - \frac{1}{1244} \right) = 6,053,188 \end{aligned}$$

$$\text{Standard Deviation} = \sqrt{\text{Var.}} = \sqrt{6053188} = 2460$$

Estimate of 1991 Stock Size = 6766 $\pm$ 2460 (68 % confidence limit)

Appendix III

Estimating the Size of the Anadromous Component of the Big Fish River Dolly Varden Stock, 1991, using Mark Recapture Data from Seining, and the Adjusted Petersen Estimate

Fish recaptured at the Fish Hole During Fall Sampling

	Tagged	Collected	1993 Recaptures
1991	435 (M)	-	-
1991	-	253 (C)	38 (R)

Anadromous Stock Size (according to Chapman, 1951):

N = Size of the population in 1991

$$N = \frac{(M + 1)(C + 1)}{R + 1} = \frac{(435 + 1)(253 + 1)}{38 + 1} = 2840$$

Sample Variance for Estimate of Stock Size (according to Chapman, 1951)

$V(N)$ = Sampling Variance

$$V(N) = \frac{N^2(C - R)}{(C + 1)(R + 2)} = \frac{2840^2(253 - 38)}{(253 + 1)(38 + 2)} = 170,680$$

$$\text{Standard Deviation} = \sqrt{V(N)} = \sqrt{170,680} = 413$$

Estimated Stock Size in 1991 = 2840 $\pm$ 413 (68% confidence limit)

Appendix IV

Estimating the Size of the Anadromous Component of the Big Fish River Dolly Varden Stock, 1991, using Mark Recapture Data from Visual Observation, and the Adjusted Petersen Estimate

Fish recaptured at the Fish Hole During Fall Sampling			
	Tagged	Collected	1993 Recaptures
1991	435 (M)	-	-
1991	-	301 (C)	58 (R)

Anadromous Stock Size (according to Chapman, 1951):

N = Size of the population in 1991

$$N = \frac{(M + 1)(C + 1)}{R + 1} = \frac{(435 + 1)(301 + 1)}{58 + 1} = 2232$$

Sample Variance for Estimate of Stock Size (according to Chapman, 1951)

$V(N)$ = Sampling Variance

$$V(N) = \frac{N^2(C - R)}{(C + 1)(R + 2)} = \frac{2232^2(301 - 58)}{(301 + 1)(58 + 2)} = 66,809$$

$$\text{Standard Deviation} = \sqrt{V(N)} = \sqrt{66,809} = 258$$

Estimated Stock Size in 1991 = 2232 $\pm$ 258 (68% confidence limit)

Appendix V

Estimating the Size of the Anadromous Component of the Big Fish River Dolly Varden Stock, 1993, using Mark Recapture Data and the Adjusted Petersen Estimate

	Tagged	Collected*	1993 Recaptures
1993	134 (M)	-	-
1994	-	512 (> 360 mm) (C)	13 (R)

Anadromous Stock Size (according to Chapman, 1951):

N = Size of the population in 1993

$$N = \frac{(M + 1)(C + 1)}{R + 1} = \frac{(134 + 1)(512 + 1)}{13 + 1} = 4947$$

Sample Variance for Estimate of Stock Size (according to Chapman, 1951)

$V(N)$ = Sampling Variance

$$V(N) = \frac{N^2(C - R)}{(C + 1)(R + 2)} = \frac{4947^2(512 - 13)}{(512 + 1)(13 + 2)} = 1,586,996$$

$$\text{Standard Deviation} = \sqrt{V(N)} = \sqrt{1,586,996} = 1260$$

Estimated Stock Size in 1993 = 4947 ± 1260 (68% confidence limit)

If we assume a similar tag loss freq. of 11.3% recorded for Dolly Varden charr (>150 mm) in southwestern Alaska (Armstrong, 1984), then the new estimate using $R = 14.5$ becomes:

Adj. Estimate of 1993 Stock Size = 4477 ± 1086 (68% confidence limit)

* To control for the effect of recruitment the smolt size classes (< 370 mm) were not included. The smolt life history stage (usually 3 years of age) is the first time the fish move to sea in the summer (i.e., point of recruitment to anadromous component).